Ice-Phase Particle Size Distributions in the May 20 MC3E Convective System: In-Situ Observations and WRF Model Simulations

Xiaowen Li[1,2] Takamichi Iguchi[3,2] Di Wu[4,2] Xiquan Dong[5] Toshi Matsui[3,2] Wei-Kuo Tao[2]

1. GESTAR Program, Morgan State University; 2. NASA Goddard Space Flight Center; 3. ESSIC, University of Maryland, College Park; 4. Science Systems and Applications, Inc. 5. The University of Arizona

Motivation

Large uncertainties exist in ice-phase microphysical processes. An example is given below for the stochastic collection process, which largely governs the particle size distributions:

$$\frac{dn_k}{dt} = \frac{1}{2}\int_0^{m_k=m_i+m_j} K_{k-j,j}\, n_{k-j}\, n_j\, dm_j - n_k \int_0^{\infty} K_{kj}\, n_j\, dm_j$$

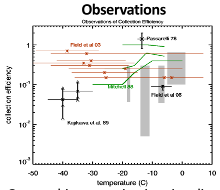
where the collection Kernel K_{ij} is given by:

$$K_{ij} = \frac{\pi}{4}\underbrace{\left(D_i + D_j\right)^2}_{\text{Size}}\underbrace{\left|v_i - v_j\right|}_{\text{fall velocity}} E_c$$

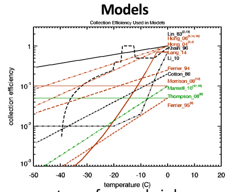
Collection Efficiency

Large Uncertainties in E_c, sometimes of more than 2 orders of magnitude:

Observations



Models

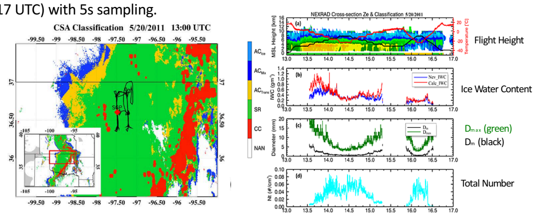


Our goal is to use in-situ size distribution measurements, surface and air-borne radar observations and GPM satellite, combined with a sophisticated spectral bin microphysical scheme, to reduce the uncertainties in E_c and to improve model simulations. As the first step, we conduct a case study and validate model simulated particle size distributions with in-situ observations.

Background

Case: May 20, 2011 meso-scale convective system at ARM SGP site during MC3E field campaign.

Observation: Air-borne in-situ measurements over the extensive stratiform region trailing a squall line. The particle size distribution data combine 2DC (120 μm ~ 900 μm) and HVPC (900 μm ~ 30000 μm). The data has 4hour-hour flight time (13 UTC to 17 UTC) with 5s sampling.



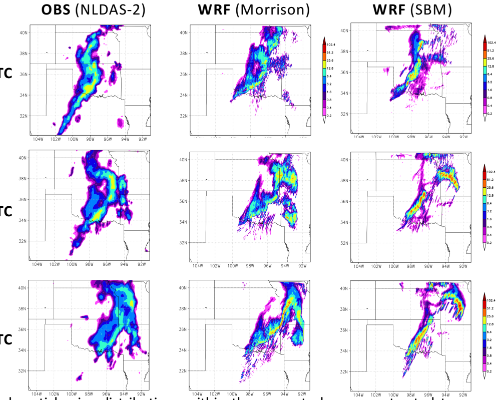
Wang, J., X. Dong, and B. Xi, 2015, J. Geophys. Res. Atmos., 120, 3533–3552, doi:10.1002/ 2014JD022795.

WRF Model: Version 3.6.1; Single domain with 2km horizontal resolution and 44 vertical levels. Simulations were initialized with NCEP FNL Operational Global Analysis starting at 00 UTC, May 20, 2011 and updated every 6 hours.

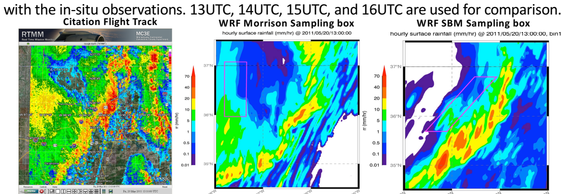
Microphysical Schemes: The Hebrew University spectral bin scheme (SBM) and the Morrison 2-moment scheme are used in simulations. The SBM scheme uses 43 mass size-doubling bins to explicitly simulate aerosol and all hydrometeor particle size distributions, including ice crystals (columns, plates and dendrites), snow aggregates, graupel, hail and cloud/rain. The Morrison scheme assumes the inverse exponential distributions for ice, snow, graupel and rain, and Gamma distribution for cloud droplets.

Model Results and Sampling Strategy

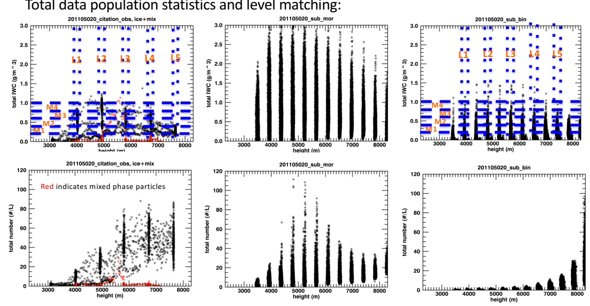
Surface rainfall comparisons with gauge data show that the WRF model reproduced the squall system and its evolution well. The Morrison scheme slightly under estimates the stratiform area. The SBM scheme misses most of the trailing stratiform region. This is caused by weaker rain evaporation and reduced near surface cool pool strengths in the SBM scheme.



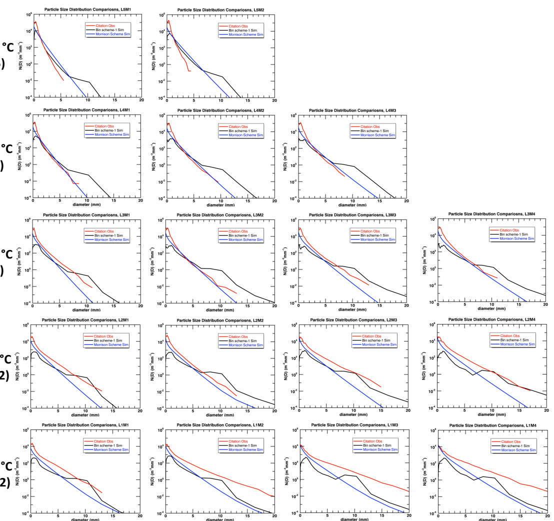
Simulated particle size distributions within the magenta box are extracted to compare with the in-situ observations. 13UTC, 14UTC, 15UTC, and 16UTC are used for comparison.



Total data population statistics and level matching:



Particle Size Distribution Comparisons



Conclusion and Future Work

- WRF satisfactorily reproduced the May 20 MC3E mesoscale convective system in terms of surface precipitation propagation and evolution, setting up the stage for more detailed comparisons.
- The Morrison 2-moment microphysical scheme produced extensive trailing stratiform rain, similar to the observation. On the other hand, the more sophisticated spectral bin microphysical scheme has little stratiform region and less total rainfall compared with the observation.
- The main reason for the differences is that the bin model produces much larger ice-phase particles compared with the Morrison scheme. This results in less evaporation and weaker cool pool near surface, producing a slower moving squall with more upright convection and little trailing stratiform region.
- Comparisons between in-situ PSD observations and WRF simulations show that both schemes simulated much larger and/or heavier particles compared with the observation. The discrepancies are more prominent at lower altitudes.
- This is an indication that the ice-phase particles are growing too fast in the simulations. Sensitivity tests on the ice-phase particle collection kernels were carried out using the bin scheme. The results will be presented tomorrow.
- Future study will include radar measurements and GPM data to confirm the results and to constrain the ice-phase particle collision/coalescence process in both bin and bulk microphysical schemes. Similar study for other GPM field campaigns (e.g., OLYMPEX) will also be carried out.